A WBEM based solution for a 4G network integrated management

Pedro Gonçalves, José Luís Oliveira, Rui L. Aguiar

University of Aveiro, DET/IT, Portugal

Abstract—**Next generation networks will put a new set of challenges related to operation and management, due to the increased complexity arising by the seamless integration of different kinds of technologies, services and terminals, and with the expected offered bandwidth. In this paper we present a Policy-based management system that is being developed inside the Daidalos IST project for such environments. This system uses Policy Based Management concepts associated with Web-Based Enterprise Management to control QoS aspects in this complex network.**

Index Terms— **Network management, PBNM, WBEM, CIM**

I. Introduction

The increasing dependency of citizens on telecommunications resources is pushing even more current technological developments in the mobile world. While 3G adoption is still in its infancy, telecommunication industry is already moving its interest into next generation networks. The high bandwidths expected, global roaming across multiple networks – wireless, mobile, cellular network, satellite-based or fixed LAN –, and increased number of users and terminals will demand for a redesign of architectures, from the infrastructure physical layer to the topmost business process layer.

However, the rapid technological and societal changes and the emergence of numerous new services have created a complex environment for network operators and a confusing situation for end users. Currently we have large developments on 2.5G and 3G technologies, on WiFi hotspots, on the appearance of WiMax as a metropolitan provider, and on the explosion of the access to home (xDSL and cable). The enhancements of existing technologies and their integration in new 4G systems will increase this complexity even more. In this context, network and the system management is a crucial factor in the success of offering new services. The operator will require a manageable network, without which no novel services will be offered.

This paper presents part of the work on network management evolution that is being carried out in the Daidalos EU project (IST). This project aims to develop and trial 4G network concepts into real instantiations in specific sites. In this paper we briefly describe QoS control management aspects through a policy-based network management (PBNM) paradigm. Section II briefly describes the overall network scenario. Section III makes some comments on PBNM and Web Based Enterprise Management (WBEM), while section IV discusses an assessment of WBEM tools available. Section V presents our usage of both concepts, while section VI discusses our conclusions.

II. A 4G Management Scenario

4G mobile communication networks are expected to provide all IP-based services over heterogeneous access technologies and provide seamless Internet access for mobile users. There is now a general mobile industrial trend to migrate the networks towards an IP based solution, as can be seen from 3GPP work, e.g.. This will allows for easy and cost effective service creation through reuse of application software as well as straightforward interoperability with existing Internet services. In addition, IP is technology independent and can thus work on any underlying access technology, paving the way to the future 4G systems. As such IP represents the glue between modern telecommunications services and the different technologies such as DVB-T, WiMax, Wi-Fi, UMTS, LAN, WLAN, Bluetooth, etc.

4G networks promise seamless handover and "always best connected" services, combining multiple radio access interfaces into a single network, the support of multiple types of services, with high speed and QoS support. In this environment, QoS, mobility and security are three different and important aspects in a 4G network. Different entities are responsible for the control of such network aspects. Figure 1 illustrates a simplified 4G network architecture [2].

A. Network entities

Figure 1 shows one administrative domain with a Core Network (CN) and Access Networks (AN) comprising three different technologies. The CN is an IPv6 backbone network connecting ANs through Core Routers (CR) and to other domains through Edge Routers (ER). The Access Routers (AR) connects the user terminal to ANs.

In each access network, QoS is controlled by one specific entity – the Access Network QoS Broker [1] (ANQoSBr). Authentication and accounting mechanisms are dealt by other entity, the A4C server (*Authentication, Authorization, Accounting, Auditing and Charging*), which controls the security and user profile aspects in each domain. For example, the A4C provides user information to the QoS brokers in order to allow them local policy decisions related to the acceptance or rejection of a call, and about QoS parameters to

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be used in each session. The CN contains it own QoS Broker (CNQoSBr) that deals with aggregates of flows that transverse the CN. It also plays an important role in the inter-domain communications (for example during a terminal handover between different administrative domains).

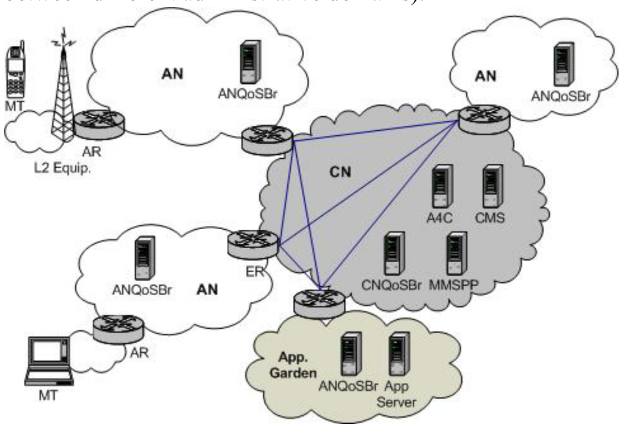

Figure 1 – A 4G network scenario – The Daidalos project architecture

Each domain also has one Central Monitoring System (CMS) to perform both active and passive measurements along the network paths and systems. It triggers probes activity, collects data periodically, and process and provides relevant information to other network management entities, such the QoS systems.

In this architecture, basic transport QoS services are provided intrinsically by the AN, while application and user-driven services are mostly controlled by the *Service Provisioning Platform* (SPP). The *MultiMedia SPP* (MMSPP) is the part of the SPP responsible for the establishment, renegotiation and termination of multimedia sessions. Based on the QoS requirements for each multimedia service and on the user profile, the MMSPP requests the adequate QoS parameters to the ANQoSBr.

All these definitions at the domain level, for example the QoS definitions, are controlled by a PBNM System. It is responsible for keeping and deploying operator policies and configuration. The PBNM Server is the interface point between the "operator" and all the network entities.

B. *QoS Management*

QoS management is a central issue on 4G networks. It has to be performed end to end, in each of the different network: in the ANs, an ANQoSBroker manages the AN resources, while the CN resources are managed by an CNQoSBroker.

The ANQoSBroker executes two actions: it authorizes admission control, based in the user profile and current network conditions, to all the flows that are created in the AN and performs configuration actions to the routers (AR) that it manages (those in its AN). As soon as a terminal starts a new flow, the AR that receives the first flow packets requests the ANQoSBroker responsible for the AR authorization to route those packets. The ANQoSBroker verifies resource usage before answering to the AR request. If there are available resources to serve the flow packets, the ANQoSBroker accepts the new packet flow, otherwise it denies the flow acceptance. The AR receives the ANQoSBroker decision and enforces it.

Configuration actions are performed by the ANQoSBroker at AR start-up time as well as when some external event force it to reconfigure the AR. Examples of such events are the observation of incoming flows with high priority, as well as the mobility of terminals with active high priority sessions. Such events sometimes do force the ANQoSBroker to drop some lower priority active sessions in order to obtain resources for the new flow. The ANQoSBroker also performs load balancing of users and sessions among networks.

The ANQoSBroker is continuously monitoring resources usage in order to perform an accurate resource management. Typically users reserve more resources then what they use later during their network session. The ANQoSBroker uses the values returned by the CMS to have a corrected view in network status and make predictions on the evolution. In the CN the resources are managed in a per-aggregate manner following the Differentiated Services (DiffServ) [3] model due to well-known scalability reasons.

The CNQoSBroker performs core network resource distribution by all the AN that belong to its domain. The ANQoSBrokers use that allocation to perform admission control for the flows that use CN resources (between different ANs). Additionally CNQoSBroker do also continuously monitor the CN resources usage by each AN. For that it schedules monitoring sessions in the CMS entity. Based on the monitoring information it receives from the CMS the CNQoSBroker periodically performs a new distribution of the CN resources and transmits that information to all the ANQoSBrokers that belong to its domain.

C. *4G Management Challenges*

Managing a 4G operator requires a complex set of configuration actions that should be coordinated in order to achieve an effective network operation. A set of serious challenges can be identified to the management activity. These challenges have to do with the diversity of the configuration actions to be performed in the operator management. For instance once a new service is created several entities need to be properly informed and configured to support the new service. The user management platform should receive the service price, the list of users authorized to make use of the new service, the accounting and charging rules of the new service, etc.. The network resource management platform should be informed about the network resource requirements for transporting the new service packets and the required QoS treatment for those packet flows. The monitoring platform should be informed about the rules that define the monitoring actions for the new flows and what QoS parameters should be measured and monitored. That list of configuration actions denote an enormous amount of configuration work, typically performed by several different persons, that need to be made in an integrated manner.

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The efficiency of an operator highly depends on the time the operator takes to implement a new service since the service is decided to be created, and on how efficiently and reliably it supports it. Without an integrated automatic equipment configuration it is very difficult to implement new service offers in a short period, specially in such a complex environment. Equipment configuration is a tedious repetitive task that should be performed in all the equipment belonging to the operator. Repetitive tasks are error-prone when they are executed by human operators. The safest manner of implement a repetitive task is to choose an automated system to make it.

Another problem is centered on consistency control. Several network control conflicts are predictable to appear when a new service is created. The physical resources are shared between the older service flows and the new service flows. The rules that define the equipment configuration have to be changed in order to serve the new flows, and the overall system has to remain stable. Some disturbance typically appears in the old services as a consequence of the new service creation. Conflicts can also appear in the rules that define the equipment behavior. A classic example is the situation where some privileges are given to a group of users and an element of that group receives a different group of privileges. For example the accountancy group traffic receives gold service treatment and John's traffic, an accountancy member as well, receives a platinum treatment. It is also a task of an integrated management to identify these inconsistencies, and derive rules precedence in a consistent manner.

Finally configuration actions should be valid over all the operator equipment, without any inconsistency in equipment configuration. But situations can arise where some equipment is not able to accept configuration changes. It is acceptable to perform a new service creation in the A4C platform when that service could not be successfully created in the network QoS resource management platform? And after verifying the (un)successfulness of the service creation in the resource management platform shouldn't the configuration changes in the user management platform be rolled-back? Those guarantees about complete and consistent equipment configuration are only usually possible by implementing the transaction concept. When a complete successful change in the configuration of all equipments all over the operator platform is possible, the changes are committed. If some of the configuration actions were not possible the changes in the remaining entities are rolled-back. This is not feasible to be done with manual configuration, or even with basic network management systems.

An answer to all these issues is can be found relying on Policy Based Network Management (PBNM) concepts and systems.

III. Policy Based Management and WBEM

A. PBNM

The PBNM paradigm defines the usage of policy rules to manage one or more entities. PBNM is not a new concept and a lot of work as been done about it. Although its implementation may vary from technology to technology, policy definition is consensual: policies are rules that determine managed entities behavior. The PBNM approach proposes an integrated management of the entire equipment scenario, having a unique point of contact with human operator: the Policy Based Network Management Server (PBNMS). The contact between human operator and the policy server is performed by a GUI where human operator performs policy edition and analyses equipment behavior after policy deployment.

The device configuration is performed automatically by the PBNMS accordingly to what is defined in the policy rules. Once new policies are defined in the PBNMS, a new reconfiguration is performed in the managed entities with minimal/no intervention of the human operator.

Adding a configuration transaction control mechanism in a PBNM solution is a relatively simple task since the same entity performs the device equipment of the entire management scenario and by the same reason PBNM reduces the inconsistent configuration actions.

Conflict detection and conflict resolution is also made easier by the PBNM approach. Since the same entity centralizes all the policy rules valid for the entire network, it is easier to analyze the policies that govern the managed entities and detect the conflicting ones. Once the detection is performed the human operator can be informed about the conflicting policies and a policy edition avoiding the conflict is possible.

B. WBEM

The number of different standardized and proprietary solutions in network and system management, defining various protocols, APIs, information models, frameworks, platforms, architectures, etc. has grown substantially in the last years. However, their integration and interoperability present problems – usually they are developed for a specific application area and are not well supported outside it.

The CIM (Common Information Model) specification [4] aims to provide an interoperable solution between all the management domains, and is part of WBEM. In fact WBEM includes [5]:

- a data model, the *Common Information Model* (CIM) standard;
- an encoding specification, *xmlCIM Encoding Specification*;
- a transport mechanism, *CIM Operations over HTTP*.

CIM is a scheme that applies the concepts of the object-oriented paradigm in the description of management entities such as systems, software, users and networks; it is based on UML (Unified Modeling Language).

This model includes expressions for common elements that must be presented to management applications (for example, object classes, properties, methods and associations). Due to its nature of expressiveness it is possible to translate between

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CIM and other information models. The elements of the model are Schemas, Classes, Properties and Methods. The model also supports Indications and Associations as types of Classes and References as types of Properties.

The operations that are defined for CIM are independent of the protocol used. However, CIM supports an XML-based protocol called WBEM for encoding CIM operations. In the future, other protocols could be defined.

In the next section we compare several open source WBEM platforms. These CIM Object Manager (CIMOM) solutions are compared concerning parameters such as its implementation technique, its support and the involvement of the industry in the project. In this study we have restricted our evaluation to a) open source solutions, b) C/C++ based, and c) available for multiple operating systems. Despite these restrictive assumptions we conclude, based on empirical evaluation of other products, that the tested CIMOM are in fact the most popular in the field.

IV. WBEM Assessment

This section describes the evaluation methodology and its results in the assessment of three CIMOM implementations: OpenWBEM [6], OpenPegasus [7] and SBLIM [8]. Several other CIMOM solutions have been left outside this study, due to the presented conditions. From this group we highlight a few: WBEMServices [9], Windows Management Instrumentation (WMI) [10], SNIA WBEM [11] and B4WBEM [12]. SNIA WBEM and WBEM Services from Sun Microsystems were not considered because of they are both developed on Java language. The Microsoft WMI platform was not considered due to the fact that it was developed just for Microsoft Windows operating system, and is not open source. The B4WBEM was rejected due to the fact that it was developed on Perl.

A. OpenWBEM

OpenWBEM is an enterprise-grade open-source implementation of WBEM, written in C++, suitable for commercial and non-commercial applications [6]. It provides a foundation for the development of management frameworks that overcome cross-platform barriers and empower true interoperability. Developers can use OpenWBEM as a management agent and WBEM framework to provide applications for configuration and change management, system health monitoring, and enterprise-wide management functionality. Project sponsors include companies like Novell and Vintela, Inc., Novell, as well as an extensive community of independent developers.

The initiative web site publishes very complete information related to the product. It includes a documentation section with a varied set of documents describing the platform architecture, development information and a *frequent asked questions* section. The web site also publishes a list of associated projects including CIMOM providers, CIM object navigators, and KDE integration tools. The projects list describes the plug-in list that implements the authentication models, the supported provider interfaces, and the provider types supported by the CIMOM.

The software releases are available in the *SourceForge* web site [13] for download, but a developers section also exists for the development community with a CVS server.

A public newsgroup is also available and the high number of posts along the time, as well as the large number of associated projects, proves the acceptation of the initiative work by the open-source community.

Novell distributes the OpenWBEM platform integrated with SUSE LINUX Enterprise Server 9 and two commercial management solutions were based on OpenWBEM: *Vintela Management Extensions* from Vintela, Inc. and *Apple Remote Desktop2* from Apple Computer, Inc.

B. OpenPegasus

OpenPegasus is an open source project from the Open Group sponsored jointly by IBM, HP and EMC [7]. The application was coded in C++ in order to translate the object concepts of the CIM objects into a programming model keeping the speed and efficiency of a compiled language. It is portable and is actually available for BeOS, BSDI, FreeBSD, HP-UX, IRIX, Linux, MacOS 7-9, and Microsoft Windows platforms.

The project has as well a big number of individual contributors, as we can see in the development area mailing lists. It is composed by a set of components: CIMOM server, CIM client, PegasusJavaClient, and PegasusCompiler.

OpenPegasus includes very complete documentation: the information is grouped in articles, business scenarios, white papers, newsletters, tutorials and project mailing lists. The development area is composed by four groups: the *architecture team* area, the *platform advocates* area, the *Pegasus Developers* area and *Pegasus Lite*. Each of those areas gives access to the work group documents including meeting minutes. The projects mailing lists show a very low activity during the last year, and the existing messages seem to belong to the group moderators.

The application access area has three types of access: a CVS server, source releases, and rpm packages. The web site gives access to a bug server where the community can report and detail the application detected bugs. The bug reports are presented with the reporter contact.

Several commercial products were derived from OpenPegasus: HP-UX SDK from HP and a management application from SSP Software technologies.

C. SBLIM

SBLIM [8] (pronounced "sublime"), the Standards Based Linux Instrumentation for Manageability, is an IBM Open Source project that intends to enhance the manageability of GNU/Linux systems based on WBEM management. The project is licensed under the GPL. It was derived from OpenPegasus, but completely rewritten in ANSI C. The application architecture is very similar to the OpenPegasus architecture, although the CIM server was specialized in the

Linux server management.

The project presents a very rich documentation set grouped in six areas: overview, programming interfaces, CIM instrumentation, CIM client applications, development tools, and monitoring. The web site also includes white paper documents and some presentation related with the project.

As in the other projects a developer area was created with the development related information: CVS server, a bug section, a patch list, news area, a download area and a tasks list. The information seems to be very complete and it is very well organized. The CVS has a web interface allowing browsing the code using the web browser.

The project is composed by 25 applications with several clients, a CIMOM server and several providers. The provider list includes providers supporting email server configuration, and a lot of Linux system configuration interfaces. All the components can be downloaded from the web site.

The news area shows a considerable number of posts sent by a wide group of developers. The posts observation shows an active group of people connected with the project development.

IBM owns a commercial product named AIX 5L Version 5.3 based on SBLIM used to perform IBM equipment management.

D. Evaluation

The current section presents the comparison results obtained from the discussed CIMOM servers (Table 1).

Considering the programming languages, and since one of our initial requirements was C/C++, the three systems are based on one of these - C++ for the OpenPegasus and OpenWBEM and C for SBLIM. The sources are publicly available and are cross-platform compliable.

The application repository was implemented in XML in the OpenPegasus project while the OpenWBEM server keeps information in MOF files and in a DBMS. This difference may be responsible for the higher memory requirements of OpenPegasus, accordingly to the results presented in [14].

Another point of evaluation was the adoption, usage, and the richness of e-groups discussions for the analyzed projects. The OpenWBEM and SBLIM projects show a regular activity inside the development community. There are also recent and successive software versions. The projects contributors/sponsors came normally from big companies (IBM, Novell, HP, ...) which use WBEM in internal products and also some internal results to influence WBEM systems [15, 16] – for example, Novell includes the OpenWBEM on its SuSE Linux distribution.

OpenPegasus and SBLIM have much richer documentation then OpenWBEM. Project mailing lists have also been considered as an evaluation factor. In this point the balance falls clearly into the OpenWBEM and SBLIM which have a wide set of discussion groups, and a permanent and continuous activity.

The project adoption group items were mostly favorable to the projects OpenWBEM and OpenPegasus. Big companies developed management solutions based in those projects. Considering the benchmarking, the differences between the platforms are not significant. In [14] it is also shown that the measured latency times had no relevant difference, but the memory requirements are favorable for the OpenWBEM implementation.

	OpenPegasus	SBLIM	OpenWBEM
Architecture			
Repository implementation	XML		MOF, DBMS
Development Language	C++	C	C++
O.S. Integration	Any	Any	Any
Remote providers		Yes	Yes
Community evolvement			
Developers evolvement (1=poor..5=very evolved)	2	3	4
Contributor/Sponsor	IBM, HP and EMC	IBM	Novell Vintela
Project Support			
Support applications (1=none..5=plenty)	2	2	4
Documentation (1=none..5=plenty)	4	4	3
Mailing lists (1=very poor..5=very used)	2	4	4
Project adoption			
Companies using open source implementations	HP	IBM	SuSE
Commercial products based on the implementation	HP-UX SDK S S P Software Technologies	IBM – AIX	Vintela Management Extensions Apple Remote Desktop 2 Novell / SuSE SLES 9

Table 1 - CIMOM server comparison

While this evaluation did not show a strong advantage from one of the three WBEM implementations, OpenWBEM seems to be a step ahead from the other two proposals. Thus, this platform was chosen to support the PBNMS development. Nevertheless, the proposed architecture does no rely on the specificities of this particular CIMOM.

V. WBEM APPLICATION TO 4G MANAGEMENT

In the policy-based management paradigm [17] the administrators, service operators, and generically management staff use of a specific console to define operational requirements, constraints and rules. Those will be converted into policies that will be spreads over the related managed entities. This section shows how WBEM model is being used in our management architecture to configure and control intermediate managing entities such as the QoSBrokers, the A4C server, the CMS and the MMSPP.

A. Policy Based Network Management Architecture

The proposed WBEM management solution is based on four main components: a CIM server, a web GUI that allows the policy information edition in the CIM server, a repository for storing policies and several providers that interface the managed entities. Figure 2 illustrates the policy server components.

The CIM server is based on the OpenWBEM CIMOM [6]. The classes' definitions are described on MOF files that are imported into the CIMOM in order to allow the creation of objects (managed entities). These class instances are then stored in the CIMOM repository from where they are accessed during the operational phase.

The user interface (GUI) is implemented as a CIM server web client that allows policies edition in the server. A new visual policy language is being developed as a way to simplify the edition and the orchestration of rules. Policies are then compiled and stored in the CIM server. Policies can be converted into several more specific rules related with different network entities. For instance, policies related with QoS, with A4C, with Multimedia and with traffic monitoring.

The QoS policies category includes configuration rules defining the QoS service attributes, local resources, network topology, etc.. These rules are transferred to the QoS management entities that use this information to define the way they manage internal QoS resources.

User profile related policies are transferred into the A4C management entities. These policies include rules defining the way how customers should be authenticated, rules defining the operator services each customer, or class of customers, is authorized to use and rules defining how the service usage will be accounted. A4C entities receive as well policies defining how the accounted information should be audited and rules defining how service's usage will be charged. Users will be organized into classes/groups according to the operator's marketing strategy.

Multimedia related policies define the multimedia services available in the network and its main parameters. These policies will be handled by a SIP application server.

Monitoring related policies define the network monitoring tests, the nodes where the tests should be performed as well as the test scheduling. The monitoring server receives the monitoring rules and spreads this information by its distributed active and passive probes. Policies are here strongly related with the characteristics of the CMS subsystem.

The human operator monitors the network behavior using the GUI: it queries the alarm list and reads the monitoring information in the monitoring server. The information received by the client from the CIMOM allows the human operator to receive continuous feedback from the network behavior and act manually or semi-automatically upon this information. At any time, the human operator can create or redefine policies in order to build management handlers for a new service or to modify operational parameters to improve the network performance and QoS availability. The communication between the CIM Server and the GUI is performed in CIM/XML over HTTP.

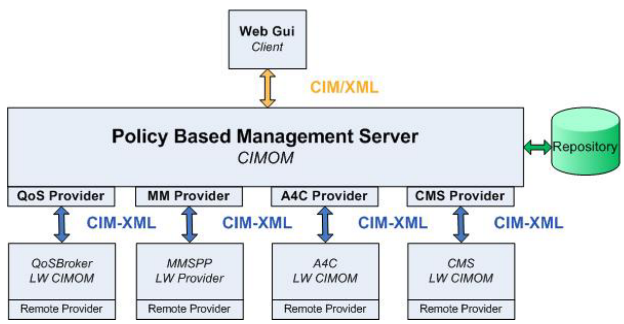

Figure 2 – WBEM PBNMS architecture.

Remote providers interface the network managed entities with the PBNMS. A provider is created per managed entity category: a QoS Provider, a Multimedia provider, an A4C provider and a Monitoring provider. The Figure 2 illustrates the providers developed inside the project.

B. Remote Provider concept

OpenWBEM provider implementation is based on a CIMOM loadable library, a UNIX .so file, completely controlled by the CIMOM. The distributed nature of 4G operator architecture requires a remote provider implementation. OpenWBEM proposes as well a remote provider concept: remote providers use a light-weight CIMOM implemented in the managed entity, that making use of a loadable library implemented provider interfaces the managed entity. Figure 3 illustrates the remote provider concept.

The main CIMOM, making use of its provider, acts as a client to the light-weight CIMOM. The communication between both CIMOMs is performed in CIM-XML over HTTP or performed in a proprietary binary protocol named ow_binary. The light-weight CIMOM interfaces the managed entity. This is exploited in the implementation of some units.

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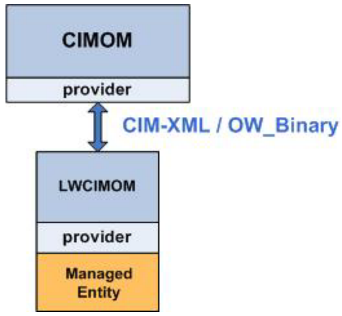

Figure 3 – Remote provider concept.

VI. CONCLUSION

The number of entities involved in the 4G operator operation, as well as its diversity creates important challenges for the management activities. Managing a 4G operator requires that all entities involved in a service offer are configured in a coherent manner. For instance, service QoS definitions should be coherent with the information present in the A4C server as well as it should be articulated with the monitoring information. A second requirement for a 4G management is an integrated configuration at the operator domain scope. For instance the service properties should be the same in the entire operator domain. Policy Based Network Management paradigm proposes an integrated management that answers the 4G management requirements. Accordingly with PBNM model, the management should have a user interface where the human operator performs policy definition. The policies defined by human operator govern the operation at the instrumentation level in the entire operator.

QoS management is an area of the major interest in a 4G operator administration. Guaranteeing QoS to the offered services makes operators to carefully define the service QoS parameters and monitor the treatment the network offers to the service packets. The WBEM architecture accomplishes the PBNM requirements, and seems to provide a proper solution to QoS support. WBEM platforms have a user interface that configures a CIM policy server. The CIM policy server interfaces the instrumentation layer using entities named as providers. In that context a WBEM based solution was explored for the QoS PBNM implementation. Several WBEM servers were analyzed in order to choose the WBEM implementation that better responds to PBNMS implementation requirements.

Despite WBEM may have several performance constraints this is not a major problem in our architecture. Although performance is important, considering that we are acting in a manager-to-manager environment it is more significant the capabilities of the management framework to develop new services and management procedures in a reduced time and cost-effective way. WBEM and PBNMS are definitely inline with this strategy.

OpenWBEM CIMOM was chosen to found our PBNMS implementation. The choice was based on two main reasons: the dynamic nature of the OpenWBEM project development and the general-purpose character of the solution.

QoS provider was developed to interface QoSBrokers, and a LDAP repository was integrated with the CIM server. Interfaces based on other protocols (COPS and SNMP) will be developed in the next future in order to interface other types of managed entities. A performance evaluation of the interfaces will be considered in order to conclude if a CIM-XML is a valid approach considering scalability issues. Providers interfacing the remaining entities are being developed as well, allowing a complete policy based management of the operator.

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